ASSESSMENT AND COMPARISON OF TONGUE POSTURE AND SAGITTAL PHARYNGEAL AIRWAY DIMENSION IN CLASS I, II, AND III MALOCCLUSION

- A CEPHALOMETRIC STUDY

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CERTIFICATE

This is to certify that **Dr.ANSHUMAN MUNDHRA,** *post graduate student (2002-2005) in the Department of Orthodontics, Tamil Nadu Government Dental College & Hospital, Chennai-03 has done this dissertation titled* **"ASSESSMENT AND COMPARISION OF TONGUE AND SAGITTAL AIRWAY DIMENSION IN CLASS I, II, AND III MALOCCLUSION - *A Cephalometric Study"*** *under our direct guidance and supervision in partial fulfillment of the regulations laid down by the Tamil Nadu Dr.M.G.R. Medical University, Chennai, for M.D.S., (Branch - V Orthodontics) Part - II Degree examination.*

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INTRODUCTION

Since the dawn of the 20th Century when orthodontics was developing as dentistry's first specialty, orthodontists have felt that there was a close association between the tongue and different malocclusions. However, it's role in causing malocclusions have never been conclusively proved. Since then, the tongue has been a subject of conflicting opinions, whether it was abnormal size, strength or posture that was responsible for the development of certain malocclusions.

In the late 40's and early 50's, **Balters**[1] stated that the tongue is the centre of reflex activity in the oral cavity and it's position must be considered carefully in planning treatment. He believed that discoordination of it's function would lead to abnormal growth and actual deformation. He has pointed out that a posterior displacement of tongue would lead to class II malocclusion and a low anterior displacement would lead to class III malocclusion. However **Balters**[1] hypothesis has never been rigorously studied.

The oral and pharyngeal regions are said to have a primary function in maintaining a patent airway. This is accomplished by dynamic muscle - skeletal balance. The mechanism of Airway maintenance is a principal determinant of the anteroposterior relationship of the placement of the tongue. Accordingly, in a mature person the variant diameters of the pharynx are determined principally by the position of tongue in relation to the maxilla and the mandible. Other than the postural implications, anatomically too, the extrinsic muscles of the tongue, particularly the genioglossus, help in maintaining airway patency.

Moss[2], while describing the functional matrix theory, goes one step further by including the pharynx into one of the oro - naso - pharyngeal functioning spaces, whose volumetric growth is the primary morphogenetic event in facial skull growth.

Knowing that the resting posture of the tongue is intimately related to the sagittal pharyngeal dimension, it is reasonable to expect that tongue posture is a reflection of airway width. Over the years, many researchers have used different methods to evaluate tongue posture. The pharynx too has been measured by different authors at various points which these authors thought, accurately gave the sagittal pharyngeal dimension.

AIMS AND OBJECTIVES

The following Aims and Objectives were formulated for present study:

1. To study the validity of **Balters**[1] hypothesis concerning tongue posture and skeletal development.

2. To study the co-relation of sagittal airway depth to tongue posture and indirectly to malocclusion.

REVIEW OF LITERATURE

The role of the tongue posture as a cause of malocclusion has evoked many conflicting and contradictory opinions from various orthodontists. Literature available in this context will be reviewed first. Researchers have, over the years, used different methods of evaluating tongue volume. These will be reviewed next. Lastly, literature on the pharngeal width, its relation to the tongue and its role in malocclusion will be reviewed.

STUDIES DONE FOR EVALUATION OF TONGUE POSTURE

Balters (1952)[1] had a unique view as far as the etiology of the development of malocclusion was concerned. To quote him "The equilibrium between tongue and cheeks, especially between the tongue and the lips in the height, breadth and depth in an oral space of maximum size and optimal limits, providing functional space for the tongue, is essential for the natural health of the dental arches and their relation to each other. Every disturbance will deform the dentition during growth, that may be impeded too. The tongue is the essential factor for the development of the dentition. It is the centre of the reflex activity in the oral cavity".

According to **Balters**[1] hypothesis, Class II malocclusions are a consequence of a backward position of the tongue which impedes the respiratory function, concomitantly leading to mouth breathing. By the same analysis, he reasoned that Class III conditions are due to a more forward position of the tongue. He explained Class I malocclusions as being due to a lack of transverse development of the dentition, as a consequence of a weakness of the tongue in comparison with the strength of the buccinator mechanism.

The main objective of **Balters**[1] treatment of Class II Div.1 was to bring the tongue forward. This was to be achieved by stimulation of the distal part of the tongue, for developing the mandible in an anterior direction to establish a Class I relationship. Conversely, for Class III malocclusion, Balters wished to get the tongue into a more backward and higher position. This would lead to a reduction of the anterior force vector, and the mandible would return to a Class I relation.

Balters[1] while emphasizing on the role of reflex mechanism and function, stated that if one wants to carry out functional orthopaedics, then it must not only bring about correction of the jaw but also effect specific dynamism in a human being which restores the regulation mechanism through the adjustment of reflex procedure and the control of the functions.

Balters[1] was also convinced about the posture of the tongue in different malocclusions. Through his appliance therapy, he sought to actively reposition the tongue by thickening or thinning out the appliance in the upper or lower jaw. He felt that this repositioning supports the correction of the malocclusion by recasting the shape of the jaw and restoration of function.

According to **Balters**[1]**,** the equilibrium between tongue and the circumoral muscles is responsible for shape of dental arches and intercuspation. The functional space for the tongue is essential to the normal development of the craniofacial system as quoted by **Thomas Rakosi**[3]. He states that, researchers now know that abnormal tongue function can be secondary adaptive or compensatory because of maldevelopment.

Mckee (1956)[4] studied tongue position in cleft patients using cephalometric headplates. Iodochoral was introduced into the one nostril and a sticky mixture of barium sulfate and gum acacia was painted on the median sulcus of the tongue and hard plate for contrast.

W.J.Tulley (1956)[5] described the adverse muscle forces and their diagnostic significance. He used cephalometric graphic studies and then classified atypical swallowing into 2 types: Nondispersing behavior of tongue and dispersing behaviour of tongue.

Donald.F.Eifert (1959)[6] did a study on tongue position in 16 yr old children. Profile cephalograms were taken at rest and at occlusion. His study proved that a high correlation exists between tongue area and mandibular length in both males and females.

A.J.Wildman (1961)[7] gave brilliant literature regarding various methods of measurement of tongue. He quoted the work done by various workers for cephalometric measurement of tongue and it's posture:

Hixon (1949) did extensive analysis of morphology and function of tongue involving linear measurement of tongue and measurement of tongue area, based on Frankfort plane.

Joanne Subtelney (1956) showed excellent analysis system designed to measure individual variation of structures of oral cavity. She used reference line passing through the direction of lips parallel to palatal plane which she called the oral reference line. She gave measurements for total oral cavity length giving proportional horizontal locations of high point of the tongue.

Wildman[7] himself proposed a system for measurement of tongue position. It involves reference plane for vertical tongue position as palatal plane and for the horizontal tongue position, as a line drawn through the tip of lower incisor parallel to palatal plane. He has included 2 variables:

a. High point of tongue to palatal plane

b. Ratio of projected high point of tongue to tip of lower incisor and oral cavity length on incisal reference line.

T.M.Graber (1962)[8] in his illustrative article, "The 3 M's" has given a broad explanation of the relation of tongue posture and each type of malocclusion. According to him, in class II Div.I there is compensatory tongue thrust, lower tongue position and increased buccinator muscle activity leading to narrowing of V-shaped maxillary arch. In class II Div. II tongue tends to accentuate the excessive curve of spee and interferes with the eruption of posterior teeth by occupying the interocclusal space. In class III the tongue appear to lie lower in the floor of the mouth and since the maxillary arch does not have the balancing effect of tongue mass, the maxillary arch is usually narrow and interocclusal space is either small or absent.

Cleall (1967)[9] used standardized cinefluorographic records of swallowing to determine the resting posture and movement patterns of the oropharyngeal structures.

Peat (1968)[10] studied the habitual postural position and resting postural position of the tongue by taking 4 lateral radiographs. He came to the conclusion that there are 2 postural positions of the tongue for each individual. He noted that the age factor must be considered in studies of tongue position as children have a higher dorsal height than adults.

Fishman (1969)[11] evaluated postural and dimensional changes in the tongue from physiological rest position to occlusion in subject with normal occlusion, malocclusion or speech defect. A series of 3 lateral radiographs were used for the study. To facilitate tracing of the tongue, a thin coating of tantalum powder was painted on median sulcus.

Vig and Cohen (1976)[12] did a serial growth study of the tongue and intermaxillary space in 50 subjects, using radiographs taken with teeth in occlusion. No contrast medium was used.

Rakosi (1982)[13] measured tongue position using lateral cephalometric radiographs with the help of a template. According to him, the dorsum of the tongue is relatively high in class II malocclusions. The tip of the tongue is retracted in cases of class III and in class II cases with nasal breathing. He noted that in class III cases a lower tongue profile is seen.

Lowe *et al.,* (1985)[14] studied the rest position of the tongue in 60 adult females with normal or anterior open bite malocclusions using 3 lateral rest position head films.

Milidonis *et al.,* (1993)[15] studied the genioglossus activity during swallowing, rest and maximal tongue protrusion in two head positions with non-invasive recording devices. They suggested that head positional difference may have an effect on genioglossus muscle activation thresholds.

B. STUDIES ON THE ROLE OF TONGUE VOLUME

Baker (1954)[16] Studied micro and macroglossia. He concluded that the growth, development and function of the tongue must be normal, if normal oral and dental relationship are to be the result. He also felt that a retracted tongue position may be a cause of distocclusion.

Hovell (1955)[10] as quoted by `John Peat' proposed that the size, shape and posture were the main factors in the formation of Dental arches.

Winders (1958)[17] did a landmark study on the force exerted on the dentition by peri-oral and lingual musculature and came to the conclusion that the tongue during function exerts a much greater force on the dentition than the peri-oral musculature.

Straub (1961)[18,19] in his series of 3 papers regarding tongue malfunction draw attention to the fact that deviated swallowing and tongue thrust were the prime causes of malocclusion.

Weinstein *et al.,* (1963)[20] spoke of the role played by the tongue in the `Equilibrium theory of tooth position' and the effects of unbalanced muscle forces on the position of teeth.

Harvold (1968)[21] showed experimental evidence to prove that large tongue are associated with broad dental arches or open bites. Conversely small tongue are associated with narrow arches. He showed that the lowering of the tongue in experimental animals lowers the mandible and the tongue moves forward. This leads to a neuromuscular conflict between the tongue and the muscle matrix outside which leads to an expansive effect and open bite.

Fishman (1969)[11] did a study on postural and dimensional changes in tongue from rest position to occlusion and he felt that abnormalities of either posture or function could possibly contribute to development of malocclusion.

Genisor (1970)[22] classified class III malocclusions and described how respiratory obstruction or enlarged adenoids could compel the tongue to be held in a low and forward position which would lead to forward posturing of the mandible and development of class III malocclusion.

Harson and Cohen (1973)[23] after a comprehensive study, could not find any correlation between tongue thrusting and malocclusion, thus disapproving the contention put forth by straub. They also quoted **Hopkins** who studied tongue position and found that the tongue is highest in class II malocclusion, lowest in class III malocclusion and intermediate in class I malocclusion.

Simard - Savoie (1976)[24] produced experimental microglossia in rat by considerably resecting the tongue. They noticed that this causes the palate to be narrower, upper incisors to be less advanced than normal and also the palatal vault to be lower.

Profitt (1978)[25] is his monumental article, "Equilibrium theory revisited" mentioned, that the clinical significance of an altered pattern of swallow probably lies in it's relationship of a different resting posture of tongue rather than the swallowing act itself.

Roehm (1982)[26] used CT scans to assess the 3 dimensional relationship of the tongue to it's surrounding space. He noticed that in openbite cases, the tongue volume was proportionately higher than normal. It was postulated that to accommodate the tongue without impinging the airway, the mandible rotates open and tongue postures forward, creating an anterior open bite.

Lowe *et al.,* (1985)[14] found that in openbite cases there was a forward positioning of the tongue to maintain the airway.

Lowe *et al.,* (1986)[27] made 3 dimensional CT reconstructions of tongue and airway in 25 adults with obstructive sleep apnea. This study showed that tongue volume increased more rapidly than airway volume in subjects with OSA. Subjects with large tongue volume were observed to experience significant complications at the time of surgical treatment.

Kazuhiko Tamari *et al.,* (1991)[28] described the relationship between the tongue volume and lower dental arch size. They concluded that both the mean tongue volume and mean lower dental arch size were significantly larger in men than in women. They also concluded that the tongue volume and arch size were significantly correlated and that these correlations tended to be higher at the more posterior part of dental arch.

Robert Lander (1991)[29] estimated tongue volume using MRI. They measured the tongue, oropharynx and oral cavity and gave the method. They were of opinion that estimating volume from MRI is accurate and reproducible to certain degree. However, defining the inferior and lateral boundaries of the tongue was found to be difficult at times and this resulted in some error in estimating volume.

C. STUDIES ON ROLE OF PHARYNX IN ETIOLOGY OF MALOCCLUSION

T.M. Graber (1959)[30] in his research study used cephalometric radiographs to determine soft tissue morphology of normal subjects during consonant sounds. Following conclusions were made: Soft palate increases in length significantly from rest to functional position: It is the third quadrant of the palate which effects the velopharyngeal seal for normal adults: The greatest extent of upward & backward movement of the palate takes place at the midpoint of the posterior superior surface of the palate: The high point of the soft palate was never involved in actual seal: The midpoint of closure during seal is normally 3-4 mm below palatal plane: The velopharyngeal value is consistently closed for all the consonant sounds.

Wildman (1961)[7] gave brilliant review of all the methods of measurement of velopharyngeal area on cephalograph done by various workers:

a. **Wolfe (1942)** presented cephalometric study of nasopharyngeal closure during rest and phonation of vowels "a" and "ae".

b. **Hixon (1949)** measured cephalograph of persons with normal and nasal speech taken during rest and phonation. Linear measurements of velopharyngeal area includes vertical shift, horizontal shift and anterior shift. It is based on Frankfort plane.

c. **King (1952)** used cephalographs from the Broadbent - Bolton Growth study to measure vertical & horizontal growth changes in oral & nasal pharynx. He used FH plane as reference line. It incorporated 3 horizontal & 5 vertical variables.

d. **Willis (1952)** presented a system based on FH plane. He also measured the area of nasopharynx and soft palate.

e. **Ricketts (1954)** suggested that the variation of cranial base might be an underlying factor affecting velopharyngeal valve competence.

f. **Joanne Subtelney's dissertation (1956)** contained excellent analysis system to measure individual variation in structures of oral & nasal area. She included 3 vertical measurements, 5 horizontal measurements, 4 measurements for cavity length and 1 measurement for velar elevation.

g. **Daniel Subtelney (1957)** published a study of growth of soft palate. He used the palatal plane as basic reference line.

h. **Brader (1957)** presented study of morphologic variations in cranial base and pharyngeal structures. He incorporated 8 angular measurements and 6 linear measurements.

i. **Hagerty (1958)** published laminographic study of posterior pharyngeal wall movement and soft palate function.

j. **Fletcher (1958)** devised a system of measurement in which the relationship of various skeletal points were expressed in terms of angular measurements. Total 10 variables were included.

Wildman[7] himself proposed a system for measurements of velopharyngeal valve. These includes 6 variables including 3 ratios. He also used 2 variables for skeletal measurements.

Bosma (1963)[31] noted that the mechanism of pharyngeal airway maintenance is a principal determinant of the anteroposterior relationship between the tongue tip and the incisors. He felt that at any given moment, mandibular position is relevant to both the head and neck posture and the pharyngeal airway. Accordingly in a mature person, the variant diameters of the pharynx in oro - facial respiration are determined principally by the position of the tongue in relation to the mandible and maxilla. In fact, the tongue support musculature also participates in the function of controlling pharyngeal diameter, particularly the genioglossus.

Michael Stepovich (1965)[32] gave illustration for cephalometric positional study of hyoid bone. He used 2 new landmarks along with the others : G (greater horn of hyoid) and L (Registration point). He also described for the first time, the hyoid plane. He included 2 linear and 5 angular measurements.

Watson *et al.,* (1968)[33] studied the relationship between airway adequacy and type of Malocclusion. They found no association between rhinomanometric measures of airway adequacy and type of Malocclusion or craniofacial Morphology.

Moss (1969)[2] while describing the Functional Matrices in facial growth, states that cell growth changes in the size, shape and spatial position and indeed the very maintenance in being, of all skeletal units are always secondary to temporally primary changes in their functional matrices. He calls the pharynx as one of the primary functional spaces. According to him, it is the volumetric growth of pharyngeal, oral or nasal spaces which is the primary morphogenetic event in facial skull growth.

Genisor (1970)[24] emphasized the importance of the pharyngeal airway. He described how the tongue would be held in an altered posture to maintain airway adequacy if there was even a slight amount of respiratory embarrassment. This forward or downward posture of tongue could lead to class III Malocclusion.

Linder - Aronson (1974)[34] demonstrated the changes in the craniofacial Morphology due to obstruction of the upper airway because of enlarged adenoids. The changes observed were : reduced facial prognathism, opening up of the Mandibular plane angle and also Mouth breathing habit. In his follow up study after adenoidectomy, he noticed that there was a reversal of these changes. He proposed that the lowered position of tongue played significant role in pathogenesis.

Profitt (1978)[25] wrote that if there is difficulty in breathing, the physiological adaptations which facilitate mouth breathing include a forward position of head on the neck and a lowered position of the mandible with a low and forward tongue posture.

Schulhof (1978)[35] described how the development of an anterior openbite can be brought in cases with respiratory obstruction. This respiratory obstruction can also lead to mouth breathing which he feels is the cause of many orthodontic problems like class II Malocclusion, buccal crossbite and vertical growth problems.

Bibby (1981)[36] noted that by measuring the pharynx between the most anterior point on the atlas and PNS point, one could get an accurate measurement of bony anteroposterior length of the pharynx at the level of cervical vertebrae I.

Vig *et al.,* (1981)[37] in their study examined the relationship between facial morphology and respiration. They concluded that the respiratory patterns between lip - incompetence, long faced and normal persons, when compared in groups are not significantly different.

Weber *et al.,* (1981)[38] did experiment to find out whether artificially induced extended head posture decreases the resistance to nasal airflow. They could not find any association between extended head posture and a decreased resistance to nasal airflow.

Ryan *et al.,* (1982)[39] gave critical review of literature concerning the effect of nasal airway functions upon dentofacial morphogenesis. After reviewing all the recent and frequently cited papers, they fail to support a consistent relationship between obstructed nasorespiratory function and adenoid facies or long face syndrome.

Sosa, Graber and Muller (1982)[40] studied post pharyngeal lymphoid tissue in Angle class I and class II malocclusions by xeroradioagraphic lateral cephalometry. They concluded that the lateral, 2-dimensional cephalogram does not seem to offer satisfactory information relating the nasopharyngeal area to class I or to class II div 1 malocclusions.

Karin Vagervik (1984)[41] designed experiments to test whether there was a morphologic response to changes in neuromuscular patterns induced due to altered mode of respiration in rhesus monkeys. The neuromuscular changes were triggered by complete nasal obstruction. Alteration was triggered again by removal of obstruction and return of nasal breathing. There was considerable variation in Morphologic response among the animals.

McNamara (1984)[42] suggested that lower pharyngeal width be measured from the intersection of posterior border of tongue and inferior border of the mandible to the closest point on the posterior pharyngeal wall. He felt that width of the lower pharynx greater than 15 mm suggested anterior positioning of the tongue.

Solow *et al.,* (1984)[43] studied the association between craniocervical angulation and craniofacial morphology, airway obstruction by adenoids and craniofacial morphology and between airway obstruction and craniocervical angulation. The observed conclusion were in agreement with the predicted pattern of associations.

Lowe *et al.*, (1985)[14] documented the relationship between tongue muscle parameters at rest and craniofacial morphology in adult human subject with normal and anterior open bite Malocclusions. They found that in patient with open bites, the tongue tip was ahead of incisal edge of lower central incisor and above the lower occlusal plane. Also, there was mandibular rotation and a forward tongue posture to maintain the airway.

Archer and Peter S.Vig (1985)[44] in their study on effects of head position on intraoral pressures in class I and class II adults, noted that every subject showed pressure changes with changes in head position. They suggested that posture may be a variable in the form/function relationship that determines skeletal form and tooth position.

Santamaria, Lowe, Fleetham and Price (1986)[45] quantified facial morphology in 25 adult males with OSA. OSA subjects showed a posteriorly positioned maxilla and mandible, a steep occlusal plane, overerupted maxillary and mandibular teeth, proclined incisors, a steep mandibular plane, a large gonial angle, high upper and lower facial heights, and an anterior open bite in association with a long tongue and a posteriorly placed pharyngeal wall. Subjects with sleep apnea demonstrated several alterations in craniofacial form that may reduce the upper airway dimensions and subsequently impair upper airway stability.

Brite Melson *et al.*, (1987)[46] described the relationship between swallowing pattern, mode of respiration and development of Malocclusion. He suggested that swallowing with tooth in contact, offers best prognosis for normal development of occlusion and Respiratory pattern may influence the development of transverse relationship resulting in development of crossbite. He proposed that the influence of deviation in swallowing and respiratory pattern depends on interaction between genetic & environmental factors.

Bacon *et al.*, (1990)[47] described the cephalometric evaluation of pharyngeal obstructive factors in patients with sleep apnea. They concluded that if anatomical rehabilitation of the pharynx is to be envisaged, the leading factors to consider should be : Soft palate length, maxillary position, chin and tongue position, in that order.

Nancy Ung *et al.*, (1990)[48] quantitatively assessed respiratory patterns and their effects on dentofacial development in 49 subjects ranging from 10-16 years. Comparisons of measured breathing modes and dentofacial characteristics revealed a weak tendency among mouth breathers toward a class II skeletal pattern and retroclination of maxillary and mandibular incisors. In contrast, subjective perception of mouth breathing was associated with increased anterior facial height and greater mandibular plane angles. Nasal power and resistance were not correlated with either dental or skeletal variables.

Luc P.M. Tourne (1990)[49] made research on long face syndrome and impairment of nasopharyngeal airway. His findings showed that the switch from a nasal to an oronasal breathing pattern induces functional adaptations that include an increase in total anterior face height and vertical development of the lower anterior face. He also found that individual variations in response should be expected from the alteration of a long face syndrome patient's breathing mode.

Donald Woodside (1991)[50] studied the amount of maxillary and mandibular growth and the direction of maxillary growth after the adenoidectomy. They detected no difference in the direction of maxillary growth between the one who had undergone adenoidectomy and the controls. But the amount of mandibular and maxillary growth were significantly greater in adenoidectomy group.

Fricke *et al.,* (1993)[51] tried to relate nasal airway, lip competence and craniofacial morphology. They came to the conclusion that there was no relationship between open mouth posture and obstructed airways. They demonstrated that some patients show an open mouth posture even though the nasal airway adequacy was normal.

Pracharktam *et al.,* (1994)[52] evaluated upright and supine cephalograms of obstructive sleep apnea syndrome. They investigated how change in posture from upright to lying down affects the upper airway passage. They couldn't find difference in the upright and supine cephalometric evaluation information.

Eung - Kwon Pae *et al.,* (1994)[53] carried out cephalometric and electromyographic study of upper airway structures in upright and supine position, to investigate the relationship between upper airway size and genioglossus Muscle activity. 16 linear and area measurement were done. They concluded that the body posture has a substantial effect on upper airway structures and muscle activity.

Ceylan and Oktay (1995)[54] studied pharyngeal size in different skeletal patterns. Lateral cephalometric headfilms of subjects with different ANB angles were taken. It has been observed that two measurements, hy (most superior and anterior point on body of hyoid bone) - apw4 (Anterior pharyngeal wall along line intersecting cv4ia and hy) and oropharynx area measurements, were affected by the change of ANB angle and two other measurement, t-ppw (t-Dorsal tongue surface intersecting occlusal plane. ppw. Posterior pharyngeal wall intersecting occlusal plane) and hy-apw2 (apw2: Anterior pharyngeal wall along line intersecting cv2ia and hy) measurements, by the sex; and that hy-apw4 measurement and oropharynx area became smaller with the increase of ANB angle.

Alan A. Lowe (1996)[55] performed cephalometric comparisons of craniofacial and upper airway structure in patients with obstructive sleep apnea. They used 10 variables for tongue, 2 variables for soft palate, 4 variables for airway & 4 variables for hyoid bone.

Taylor *et al.,* (1996)[56] gave brilliant literature regarding the soft tissue growth of the oropharynx. With the help of lateral cephalogram, they demonstrated that hyoid bone descends and moves slightly anterior upto age 18. The soft palate increased 1 mm in length and 0.5 mm in thickness every 3 years after age 9. Thus, in general, two periods of accelerated change (6-9 yrs and 12-15 yrs) and two periods of quiescence (9-12 yrs and 15-18 yrs) were identified for pharyngeal soft tissue.

Trotman *et al.,* (1996)[57] studied the association of lip posture, sagittal airway size and tonsil size separately with facial morphology under selected cephalometric measures. They observed that open lip posture, reduced sagittal airway and large tonsils were each associated statistically with a characteristic but different skeletal configuration. This association was proportional. Reduced sagittal airway was associated with en bloc backward relocation of maxilla and mandible without affecting SNA and SNB as S-N dimension shortened proportionally. Large tonsils were associated with more forward relocation and rotation of the maxilla and mandible and increased SNA and SNB angles. It was concluded that lip posture, sagittal airway size and tonsil size represent three different and unrelated phenomenon with respect to their effects on craniofacial growth and form.

Eung - kwon pae *et al.,* (1997)[58] did cephalometric study to establish relation between pharyngeal length and open bite. A cephalometric variable, vertical airway length (VAL) was used. They concluded that pharyngeal length may be a convenient indicator to diagnose open bite.

Alan .A. Lowe (1997)[59] carried out a study to test the relative contributions of specific cephalometric measurements to obstructive sleep apnea severity. He revealed that extended and forward natural head posture, lower hyoid bone position, increased soft palate and tongue dimension and decreased airway dimension had higher association with OSA severity.

Huggare (1997)[60] in his study explained the relationship between nasorepiratory function and variable of head posture. Natural head position cephalograph were used along with pressure flow technique to measure airflow rate. The results showed a trend towards enlarged craniocervical angulation and forward inclination of cervical spine in subjects with relatively large nasal cross-sectional area, which is opposite to general opinion.

Murat Ozbek *et al.,* (1997)[61] Studied the change in Oropharyngeal airway dimensions due to functional orthopaedic treatment in skeletal class II cases. They suggested that the Oropharyngeal airway dimension increases in certain skeletal class II growing subjects when treated with functional appliance.

Katherine Vig (1998)[62] reviewed all the available evidence for orthodontic relevance of nasorespiratory obstruction and it's effect on facial growth. She suggested that more rigorous criteria is required to gain a more rational approach to treatment recommendations.

S.Takahashi *et al.,* (2002)[63] described the effect of change of breathing modes and body position on the genioglossus and geniohyoid muscle activity. In this electromyographic study, they concluded that the change in breathing mode and body position significantly affect genioglossus muscle activity but do not affect geniohyoid muscle activity.

MATERIAL AND METHODS

SAMPLE SELECTION

The pretreatment cephalograms of patients of age group 9-15 yrs with different skeletal types were taken. A total of 50 lateral cephalograms were obtained of which 20 were class I, 20 were class II and 10 were class III.

The skeletal type of each sample was determined by using following criteria: SNA, SNB, ANB, wits analysis, facial plane, E-plane and Angle of convexity.

METHODOLOGY

The cephalometric apparatus used for obtaining lateral cephalograms was the "PM 2002 CC Proline (Finland)". The radiographs were exposed at 75 kv/3 milliamperes with a 5ft. 2" film focus distance and a 6" distance between the film and mid sagittal plane. The radiographs were exposed for 3 second (Fig.1).

As the lateral cephalograms were taken on the same machine operated by one single technician, any errors due to technique or operator were eliminated.

In order to standardize the technique, a set of instructions were given to the patient before the lateral cephalogram was taken. The operator counted aloud numbers from 1 to 15, and the patient was asked to swallow at the count of 5 and relax. The radiograph was taken at the count of 15. The tongue had 10 seconds to relax after the swallow. (Fig.2).

Thereafter, each cephalogram was manually traced on lacquered polyester acetate papers (Garware and Co., India) using a 0.3 mm lead pencil under similar conditions (Fig.3).

The tracings of all the lateral cephalograms were studied to assess the tongue position and the pharyngeal airway width. Altogether 10 parameters were used the tongue position and 9 parameters were used to determine the oropharyngeal width.

LANDMARKS, LINES AND PLANES

All the landmarks, lines and planes employed are taken from **Rakosi**[13] and from **Athanasiou**[64] except, tb2 and ppwb2. The two are added to clearly elucidate **McNamara's**[42] measurements of lower pharyngeal width.

tb2 and ppwb2 - **McNamara**[42] had described lower pharyngeal width as the distance between the posterior pharyngeal wall and the base of the tongue measured between the point where these structures were intersected by the mandibular plane.

SELECTION OF VARIABLES

Tongue Position

Any successful analysis to study tongue posture would depend on the right choice of a reference line. The preconditions for a reference line that would serve the purpose, according to **Rakosi**[13], are:

1. The greatest possible area of the tongue should be above the line.
2. It should be independent of variation in skeletal structures.
3. It should relate to the anatomical and functional properties of the tongue.
4. It should remain constant in relation to changes in tongue position.
5. Its determination should be as simple as possible.

Measurements Tg1 to Tg7 were obtained using Rakosi's template. Other parameters like Ut-NL, TGH and TGL were also used to assess the tongue.

Sagittal pharyngeal airway width

A total of 9 parameters described by **Athanasiou**[64] were used to measure the sagittal airway width. This was done to ensure that the width of the oropharynx was measured all along its length.

AA-PNS, BA-PNS, P3 and ***Ptm-PPW2*** - measured the oropharynx at higher points along its length and helped to ascertain the upper oropharyngeal width.

PAS, LPW, MP-LP, apw4-ppw4 and apw2-ppw2 were parameters which measured the oropharynx at some what lower points along its length. Thus these parameters helped us to ascertain the lower oropharyngeal width.

ASSESSMENT OF TONGUE RELATIONSHIP

A. Landmarks for assessment of tongue position

ANS - Spinal point - apex of anterior nasal spine

E - The most inferior and anterior point on the epiglottis

ii - Midpoint of incisor overlap.

MC - Point on cervical, distal third of last permanent erupted molar.

O - Middle of the linear distance U-ii, on the MC - ii line,

Ptm - Pterygomaxillary point - The intersection between the nasal floor and posterior contour of maxilla.

TT - The tip of tongue

U - The tip of uvula or it's projection on the MC - ii line.

ut - Point on the dorsum of the tongue. The nearest point on the contour of the tongue to maxillary plane.

B. Reference lines

Ltg1 - Line through point O and U

Ltg2 - line constructed on point O of the MC - ii line, producing an angle of 30° with MC - ii line.

Ltg3 - Line constructed on point O of the MC - ii line, producing an angle of 60° with MC - ii line

Ltg4 - The perpendicular bisection line on point O to the MC - ii line.

Ltg5 - Line constructed on point O of the MC-ii line, producing an angle of 120° with the MC-ii line.

Ltg6 - Line constructed on point O of the MC - ii line, producing an angle of 150° with MC - ii line.

Ltg7 - Line through point O and ii.

NL - Nasal line - line connecting the anterior nasal spine and pterygomaxillare.

C. Variables

Tg1 - Partial length of tongue - linear distance between point O and intersection point of Ltg1 line and the contour of the tongue.

Tg2 - Partial length of tongue - linear distance between point O and the intersection point of Ltg2 line and the contour of the tongue.

Tg3 - Partial length of tongue- linear distance between point O and the intersection point of Ltg3 line with the contour of the tongue.

Tg4 - Partial length of tongue - linear distance between point O and intersection point of Ltg4 line with the contour of the tongue.

Tg5 - Partial length of tongue - linear distance between point O and intersection point of Ltg5 line with the contour of the tongue.

Tg6 - Partial length of tongue - linear distance between point O and intersection point of Ltg6 line with the contour of the tongue.

Tg7 - Partial length of tongue - linear distance between point O and intersection point of Ltg7 line with the contour of the tongue.

TGL - Tongue length - linear distance between E and TT

TGH - Tongue height - linear distance along the perpendicular bisector of the E-TT line to the tongue dorsum

Ut-NL - The shortest distance between the dorsum of the tongue (from point Ut) and maxillary plane (NL).

ASSESSMENT OF PHARYNGEAL RELATIONSHIP

A. Landmarks and definitions

AA - The most anterior point on the atlas vertebra.

ANS - Spinal point - the apex of anterior nasal spine.

APW2 - The anterior pharyngeal wall along the line intersecting CV2ia and hyoid.

APW4 - The anterior pharyngeal wall along the line intersecting CV4ia and hyoid.

Ba - Basion - The most posteroinferior point on the anterior margin of foramen magnum.

CV2ia - The most antero-inferior point on the corpus of the second cervical vertebrae.

CV4ia - The most antero-inferior point on the corpus of the fourth cervical vertebrae.

hy - The most superior and anterior point on the body of hyoid bone.

Lp - Point on the anterior wall of nasopharynx.

Mp - Point on the posterior wall of nasopharynx.

PNS - The tip of posterior nasal spine - the most posterior point at the sagittal plane on the bony hard palate.

PPW2 - Posterior pharyngeal wall along the line intersecting CV2ia and hy.

PPW4 - the posterior pharyngeal wall along the line intersecting CV4ia and hy.

Ptm - Pterygomaxillary point - the intersection between the nasal floor and posterior contour of maxilla.

PPwb - The intersection point of a line from point B through GO and the base of the posterior pharyngeal wall.

tb - The intersection point of a line from point B through Go and the base of the tongue.

PPwb2 - The intersection point of the mandibular plane and the posterior pharyngeal wall.

tb2 - The intersection point of the mandibular plane and the base of the tongue.

B. Variables

AA-PNS - linear distance between the most anterior point on the atlas vertebra and the tip of posterior nasal spine.

apw2-ppw2 - The pharyngeal depth - linear distance on the line connecting the point hy and point CV2ia, between the intersection point on the anterior and on the posterior pharyngeal walls respectively.

apw4-ppw4 - The pharyngeal Depth - linear distance on the line connecting the point hy and the point CV4ia, between the intersection point on the anterior and posterior pharyngeal walls respectively.

Ba - PNS - Dimensions of the bony pharynx - linear distance between point Ba and PNS.

Mp-Lp - The smallest distance between the anterior wall (LP) and posterior wall (MP) of the oropharynx.

P3 - The distance from the pterygomaxillary point (ptm) to the posterior pharyngeal wall along the line from the pterygomaxillary point to the basion.

Ptm-Ppw - The Depth of the nasopharynx. The linear distance between the pterygomaxillary point (ptm) and the intersection point between the palatal plane and the posterior wall of the nasopharynx.

PAS - Posterior airway space - linear distance between a point on the base of the tongue (tb) and another point on the posterior pharyngeal wall (ppwb) both determined by an extension of a line from point B through GO.

LPW - Distance between a point on the tongue (tb2) and the posterior pharyngeal wall (ppwb2) both determined by an extension of the mandibular plane and the points where it cuts the outline of the tongue and posterior pharyngeal wall.

Thus, a total of 19 variables were choosen: 10 for tongue assessment and 9 for pharyngeal assessment.

The Statistical Method

1. **Mean** - It is defined as the sum of the observations, divided by number of observations.

$$\bar{x} = \frac{\Sigma x}{n}$$

Where, x = Variable, n = Samples

2. **Standard Deviation** - It is defined as the positive square root of arithmetic mean of sum of squares of deviations taken from their mean.

$$S.D. = \frac{\Sigma (x-\bar{x})^2}{n - 1}$$

Where, $\bar{x}$ = Mean

3. **Analysis of Variance (ANOVA)** - Here, comparison was done among all the groups. This test indicated whether any significance existed between the various groups. However this analysis did not tell us among which group the significance existed.

ANOVA (One way Analysis of Variables)

Source of Variation	**Degrees of freedom**	**Sum of squares**	**Mean sum of squares**	**F-Ratio**
Between Groups	n_1	s_1	$mss_1 = \frac{S_1}{n_1}$	$F = \frac{mss_1}{mss_2}$
Within Groups (Error)	n_2	s_2	$mss_2 = \frac{S_2}{n_2}$	
Total	$n_1 + n_2$			

4. **Student's Unpaired t-test** - Since the ANOVA test did not tell us among which groups the significance existed, the values were subjected to the Student's Unpaired t-test. This clearly indicated between which groups the significance existed.

$$`t' = \frac{\bar{X}_1 - \bar{X}_2}{SE\,(X_1 - X_2)}$$

Where S.E.$(\bar{X}_1 - \bar{X}_2)$ = Standard errors of difference $(\bar{X}_1 - \bar{X}_2)$

$$S \quad \frac{1}{n_1} + \frac{1}{n_2}$$

Here S = Combined standard deviation

$$S \quad \frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}$$

and S_1 = Standard deviation of the I[st] variable

S_2 = Standard deivation o the II[nd] variable

$\bar{X}_1$ = Mean of the I[st] variable

X_1 = Mean of the II[nd] variable

n_1 = Number of samples in I[st] variable

n_2 = Number of samples in II[nd] variable

$n_1 + N_2 - 2$ = Degree of freedom

The following level of significance was undertaken:

$p < 0.01$ - Highly significant

$p < 0.05$ - Significant

$p > 0.05$ - Not significant

RESULTS

All the 19 variables were subjected to ANOVA and unpaired t-test. The following results were seen:

The measurements obtained for parameters Tg1, Tg2, Tg3 and Tg4 showed no significant difference between any of the classes ($p>0.05$). This indicates that the root and posterior aspect of the dorsum of the tongue lie at the same level in the palate in all the classes of Malocclusion.

Tg5 The anterior part of the middle aspect of the tongue in class III cases lies at a significantly lower level than class I and class II cases. This difference is highly significant between class I and class III cases ($p<0.01$). In class I and class II the tongue lies nearly at the same level ($p>0.05$). Significance is at 5% level between class II and class III ($p<0.05$)

Tg6 Represents the anterior part of the tongue. In class III cases the tongue lies at highly significant lower level than class I ($p<0.01$). Also when compared to class II cases, the difference is significant ($p<0.05$).

Tg7 Represents the tip of the tongue. The tip of tongue is retracted in class II cases significantly when compared to class I cases ($p<0.01$). This variable has been found to be highly significant. In class III too, the tongue is retracted in comparison with class I cases, though to lesser degree ($p<0.05$).

TGL Tongue length is significantly shorter in class III cases when compared to class I and class II cases ($p<0.05$). In class I and class II cases, the tongue is nearly of the same length (p>0.05)

TGH Tongue height is not significantly different in class I, class II and class III cases (p>0.05).

The variables AA-PNS, BA-PNS, P3 and ptm-ppw measured the nasopharynx at higher points along it's length. These variables represented the upper oropharyngeal width. According to this study, these variables did not vary significantly among class I, class II and class III malocclusions.
(p>0.05).

Apw2 At the level of second cervical vertebrae, the sagittal

Ppw2 pharyngeal airway dimension is much greater in class III cases when compared to class I and class II cases. (p<0.05) This indicates that in class III cases, the width of the oropharynx is significantly increased.

MP-LP This represents the shortest distance between the anterior and posterior pharyngeal walls in oropharynx. This variable is highly significantly greater in class III when compared to class II (p<0.01) It also shows significant increase in class III as compared to class I (p<0.05) Thus, as the above parameters, this indicates that the width of the oropharynx is significantly increased in class III cases.

LPW This variable is greatly increased in class III cases. It shows high significance when compared between class III and class II (p<0.01) and significance when compared between class I and class III (p<0.05) Thus, the posterior airway space or the width of oropharynx is significantly increased in class III cases.

PAS This parameter again shows an increase in class III cases as compared to class I and class II ($p<0.05$) which is consistent with the above highlighted parameters related to sagittal lower oropharyngeal dimension.

To take a panoramic view of the results of the whole study, we see that the tongue posture varies in different malocclusion only at the anterior aspect of the tongue, while the pharyngeal airway width is increased in class III malocclusion only at lower length of the oropharynx.

Table 4 a - Comparison of classes by ANOVA in Tg1

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	51.28	2	25.64	1.24	0.300	NS
Within Classes	974.00	47	20.72			
Total	1025.28	49				

Table 4 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg1

Parameter	Class	Mean	SD	t-value	p-value	significance
Tg1	I	34.10	3.11	1.61	0.117	NS
	II	31.90	5.28			
	I	34.10	3.11	1.10	0.280	NS

	III	32.40	5.38			
	II	31.90	5.28	0.24	0.810	NS
	III	32.40	5.38			

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 5 a - Comparison of classes by ANOVA in Tg2

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	71.07	2	35.53	2.18	.123	NS
Within Classes	762.95	47	16.23			
Total	834.02	49				

Table 5 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg2

Parameter	Class	Mean	SD	t-value	p-value	significance
Tg2	I II	26.40 23.75	3.50 4.04	2.22	.033	S
	I III	26.40 25.40	3.50 4.95	.64	.526	NS
	II III	23.75 25.40	4.04 4.95	.98	,336	NS

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 6 a - Comparison of classes by ANOVA in Tg3

Source of Variation	SS	df	MSS	F-value	p-value	Significance

Between Classes	37.87	2	18.93	1.40	.25	NS
Within Classes	634.55	47	13.50			
Total	672.42	49				

Table 6 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg3

Parameter	Class	Mean	SD	t-value	p-value	significance
Tg3	I	21.6	3.20	1.69	.100	NS
	II	19.75	3.71			
	I	21.6	3.20	1.13	.267	NS
	III	20.00	4.45			
	II	19.75	3.71	.16	.872	NS
	III	20.00	4.45			

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 7 a - Comparison of classes by ANOVA in Tg4

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	31.48	2	15.74	1.24	0.29	NS
Within Classes	592.20	47	12.60			
Total	623.68	49				

Table 7 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg4

Parameter	Class	Mean	SD	t-value	p-value	significance
Tg4	I	19.00	2.85	1.23	.226	NS
	II	17.70	3.77			
	I	19.00	2.85	1.52	.139	NS
	III	17.00	4.32			
	I	17.70	3.77	.46	.651	NS
	III	17.00	4.32			

* ANOVA Test shows No significance at 5% level ($p>0.05$)

* Unpaired t-test shows No significance between the 3 classes at 5% level ($p>0.05$)

Table 8 a - Comparison of classes by ANOVA in Tg5

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	103.087	2	51.54	3.31	.045	S
Within Classes	731.037	47	15.55			
Total	834.12	49				

Table 8 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg5

Parameter	Class	Mean	SD	t-	p-	significance

				value	value	
Tg5	I II	19.50 17.83	3.17 4.41	1.38	.176	NS
	I III	19.50 15.60	3.17 4.35	2.80	.009	HS
	II III	17.83 15.60	4.41 4.35	1.31	.041	S

* ANOVA Test shows significance at 5% level (p>0.05)

* Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- High Significance at 1% level between Cl.I & Cl III (p<0.01)
- Significance at 5% level between Cl. II & Cl.III (p<0.05).

Table 9 a - Comparison of classes by ANOVA in Tg6

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	209.080	2	104.54	4.26	.019	S
Within Classes	1151.10	47	24.49			
Total	1360.18	49				

Table 9 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg6

Parameter	Class	Mean	SD	t-value	p-value	significance
Tg6	I	23.30	4.21	1.22	0.229	NS

	II	21.40	5.54			
	I	23.30	4.21	3.21	.003	HS
	III	17.70	5.08			
	II	21.40	5.54	1.77	0.047	S
	III	17.70	5.08			

*ANOVA Test shows significance at 5% level (p>0.05)

*Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- High Significance at 1% level between Cl I & Cl III (p<0.01)
- Significance at 5% level between Cl. II & Cl.II (p<0.05).

Table 10 a - Comparison of classes by ANOVA in Tg7

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	224.28	2	112.14	3.93	.0263	S
Within Classes	1339.10	47	28.49			
Total	1563.38	49				

Table 10 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg7

Parameter	Class	Mean	SD	t-value	p-value	significance
Tg7	I	31.40	4.02	2.82	.008	HS
	II	27.30	5.11			

	I III	31.40 29.70	4.02 7.72	2.21	.035	S
	II III	27.30 29.70	5.11 7.72	.26	.80	NS

*ANOVA Test shows significance at 5% level (p>0.05)

*Unpaired t-test shows:

- High significance at 1% level between Cl.I & Cl.II (p<0.01)
- Significance at 5% level between Cl I & Cl III (p<0.05)
- No Significance between Cl. II & Cl.II (p>0.05).

Table 11 a - Comparison of classes by ANOVA in ut-NL

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	3.78	2	1.89	.093	.91	NS
Within Classes	947.60	47	20.16			
Total	951.38	49				

Table 11 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in Tg8

Parameter	Class	Mean	SD	t-value	p-value	significance
Ut-Nl	I II	8.45 8.15	3.02 5.85	.20	.840	NS
	I	8.45	3.02	.59	.557	NS

	III	7.70	3.71			
	II	8.15	5.85	.22	.827	NS
	III	7.70	3.71			

* ANOVA test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between 3 classes at 5% level (p>0.05)

Table 12 a - Comparison of classes by ANOVA in TGL

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	737.47	2	368.73	4.97	.011	S
Within Classes	3486.85	47	74.18			
Total	4224.32	49				

Table 12 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in TGL

Parameter	Class	Mean	SD	t-value	p-value	significance
TGL	I	78.10	8.16	2.60	.063	NS
	II	71.45	8.00			
	I	78.10	8.16	2.70	.012	S
	III	68.70	10.57			
	II	71.45	8.00	.80	.042	S
	III	68.70	10.57			

* ANOVA Test shows significance at 5% level (p>0.05)

* Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- Significance at 5% level between Cl I & Cl III ($p<0.05$)
- Significance at 5% level between Cl. II & Cl.III ($p<0.05$).

Table 13 a - Comparison of classes by ANOVA in TGH

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	48.03	2	24.01	1.110	0.338	NS
Within Classes	1017.35	47	21.65			
Total	1065.38	49				

Table 13 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in TGH

Parameter	Class	Mean	SD	t-value	p-value	significance
TGH	I	33.40	3.65	1.49	0.146	NS
	II	31.65	3.80			
	I	33.40	3.65	0.30	0.766	NS
	III	34.00	7.38			
	II	31.65	3.80	1.16	0.255	NS
	III	34.00	7.38			

* ANOVA test shows No significance at 5% level ($p>0.05$)

* Unpaired t-test shows No significance between 3 classes at 5% level (p>0.05)

Table 14 a - Comparison of classes by ANOVA in AA - PNS

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	96.58	2	48.29	2.56	.087	NS
Within Classes	884.53	47	18.81			
Total	981.12	49				

Table 14 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in AA-PNS

Parameter	Class	Mean	SD	t-value	p-value	significance
AA-PNS	I	34.70	4.26	1.35	.186	NS
	II	36.53	4.32			
	I	34.70	4.26	1.13	.269	NS
	III	32.80	4.54			
	II	36.53	4.32	2.19	.077	NS
	III	32.80	4.54			

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 15 a - Comparison of classes by ANOVA in BA - PNS

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between	57.78	2	28.89	1.73	.187	NS

Classes						
Within Classes	781.50	47	16.62			
Total	839.28	49				

Table 15 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in BA - PNS.

Parameter	Class	Mean	SD	t-value	p-value	significance
BA - PNS	I	46.65	4.15	1.26	.214	NS
	II	48.35	4.37			
	I	46.65	4.15	.70	.489	NS
	III	45.60	3.20			
	II	48.35	4.37	1.76	.089	NS
	III	45.60	3.20			

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 16 a - Comparison of classes by ANOVA in P3

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	70.75	2	35.38	2.29	0.112	NS
Within Classes	725.75	47	15.44			
Total	796.50	49				

Table 16 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in P3

Parameter	Class	Mean	SD	t-value	p-value	significance
P3	I	25.80	2.28	1.06	0.297	NS
	II	27.05	4.76			
	I	25.80	2.28	1.59	0.123	NS
	III	23.80	4.66			
	II	27.05	4.76	1.77	0.087	NS
	III	23.80	4.66			

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 17 a - Comparison of classes by ANOVA in ptm-ppw

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	90.72	2	45.36	2.70	0.078	NS
Within Classes	790.80	47	16.83			
Total	881.52	49				

Table 17 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in ptm-ppw

Parameter	Class	Mean	SD	t-value	p-value	significance
ptm-ppw	I	26.00	3.13	.53	.60	NS
	II	26.60	3.99			
	I	26.00	3.13	1.86	0.074	NS
	III	23.00	5.79			
	II	26.60	3.99	2.00	0.055	NS
	III	23.00	5.79			

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 18 a - Comparison of classes by ANOVA in ApW2-PpW2

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	154.06	2	77.03	4.44	0.017	S
Within Classes	814.59	47	17.33			
Total	968.65	49				

Table 18 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in ApW2-PpW2

Parameter	Class	Mean	SD	t-value	p-value	significance
ApW2-PpW2	I	13.05	4.47	.06	.955	NS

	II	12.98	3.76			
	I III	13.05 17.40	4.47 4.30	2.54	0.017	S
	II III	12.98 17.40	3.76 4.30	2.90	0.007	HS

* ANOVA Test shows significance at 5% level (p>0.05)

* Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- Significance at 5% level between Cl I & Cl III (p<0.05)
- High Significance at 1% level between Cl. II & Cl.III (p<0.01).

Table 19 a - Comparison of classes by ANOVA in ApW4-PpW4

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	39.03	2	19.51	1.34	.26	NS
Within Classes	679.95	47	14.46			
Total	718.98	49				

Table 19 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in ApW4-PpW4

Parameter	Class	Mean	SD	t-value	p-value	significance
ApW4-PpW4	I II	14.75 12.90	3.96 3.11	1.64	.109	NS

	I III	14.75 14.60	3.96 4.70	.09	.927	NS
	II III	12.90 14.60	3.11 4.70	1.19	.245	NS

* ANOVA Test shows No significance at 5% level (p>0.05)

* Unpaired t-test shows No significance between the 3 classes at 5% level (p>0.05)

Table 20 a - Comparison of classes by ANOVA in MP-LP

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	64.63	2	32.32	4.01	0.025	S
Within Classes	379.15	47	8.07			
Total	443.78	49				

Table 20 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in MP-LP

Parameter	Class	Mean	SD	t-value	p-value	significance
MP-LP	I II	11.10 10.55	2.99 2.82	0.60	0.553	NS
	I III	11.10 13.60	2.99 2.55	2.26	0.032	S
	II III	10.55 13.60	2.82 2.55	2.88	0.008	HS

* ANOVA Test shows significance at 5% level (p>0.05)

*   Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- Significance at 5% level between Cl I & Cl III (p<0.05)
- High Significance at 1% level between Cl. II & Cl.III (p<0.01).

Table 21 a - Comparison of classes by ANOVA in LPW

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	115.51	2	57.75	4.49	.016	S
Within Classes	603.68	47	12.84			
Total	719.20	49				

Table 21 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in LPW

Parameter	Class	Mean	SD	t-value	p-value	significance
LPW	I	11.85	3.44	.26	.795	NS
	II	11.58	3.22			
	I	11.85	3.44	2.47	.02	S
	III	15.50	4.50			
	II	11.58	3.22	2.75	.01	HS
	III	15.50	4.50			

*ANOVA Test shows significance at 5% level (p>0.05)

*Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- Significance at 5% level between Cl I & Cl III (p<0.05)

- High Significance at 1% level between Cl. II & Cl.II ($p<0.01$).

Table 22 a - Comparison of classes by ANOVA in PAS

Source of Variation	SS	df	MSS	F-value	p-value	Significance
Between Classes	95.44	2	47.72	4.17	.0215	S
Within Classes	537.87	47	11.44			
Total	633.32	49				

Table 22 b - Student's unpaired t-test for comparison of Class I, Class II & Class III in PAS

Parameter	Class	Mean	SD	t-value	p-value	significance
PAS	I	11.33	3.33	.15	.992	NS
	II	11.18	2.93			
	I	11.33	3.33	2.38	.024	S
	III	14.70	4.27			
	II	11.18	2.93	2.66	.013	S
	III	14.70	4.27			

*ANOVA Test shows significance at 5% level ($p>0.05$)

*Unpaired t-test shows:

- No significance between Cl.I & Cl.II
- Significance at 5% level between Cl I & Cl III ($p<0.05$)
- Significance at 5% level between Cl. II & Cl.II ($p<0.05$).

DISCUSSION

Over the years, various orthodontists have expressed radically different views on the role of the tongue in causing malocclusion. **Balters**[1] was of view that the maximum power of the muscle activity is not so important as the orderly coordination of the manifold function. Thus malocclusion must be regarded as a disturbance of that coordination. He believes that the tongue was the most important factor in causing malocclusion and felt that if functional orthodontics was to be stable, then along with the repositioning of the jaw, a correct tongue position too would have to be obtained. This would lead to a changed reflex activity in the oral cavity and in turn, render the corrected jaw position stable. We know that the tongue posture is a reflection of the sagittal pharyngeal dimension. This is concomitant with the fact that, the primary function of the oral and pharyngeal spaces is to maintain "airway patency". Therefore any sort of respiratory embarrassment because of enlarged tonsils or other factors would naturally posture the tongue forward. This intimacy between the tongue posture and the pharyngeal airway dimension is not only functional in nature, but also morphologic. Some extrinsic muscles of the tongue, specifically the genioglossus help in maintaining airway patency.

Some studies have been undertaken to assess the posture of the tongue. Over the years researchers have measured the sagittal pharyngeal dimension at various points.This study tries to correlate the tongue posture and airway dimension with various skeletal types.

It is seen that the root and posterior aspect of the dorsum of the tongue lie at the same level in the palate in all the classes of malocclusion. Thus the posterior part of tongue is not affected by the position of the mandible and it's relation with the cranium.

It is apparent that the anterior aspect of the tongue lies at considerably lower levels in class III than in class I and II. **McNamara**[42] explains that the forward and downward positioning of the tongue occurs to maintain airway patency.

The tip of the tongue is retracted in class II cases more than class I and class III cases. The total tongue length is shorter in class III cases. However the height of the tongue is almost same in all the malocclusions.

The upper pharyngeal dimension or nasopharynx is same in all the malocclusion. Thus the position of tongue and the position of mandible do not affect the width of the nasopharynx.

The lower pharyngeal dimension or the oropharynx is much greater in the class III cases when compared to class I and class II cases. According to **McNamara**[42], an increase of LPW dimension over 15mm is indicative of a forwardly placed tongue. The mean value of this variable in class III was found to be 15.5 thus confirming the forward position of tongue. **McNamara**[42] and other orthodontists have felt that this increased airway dimension of the lower pharynx occurs because of a forward positioning of the tongue. It was also correlative since we have seen that the tongue in class III cases was placed lower and forward.

However, this sort of data should be interpreted very critically as these observations can be argued from both sides of the coin. **Melvin Moss**[2] has a completely opposing view to that of **McNamara**[42] and other orthodontists. He states that the postnatal development of the tongue is also integrally related to the acquisition of an open masticatory cavity. It is this expansion of the available performance area which makes the anteriorward elongation and greater motility of tongue feasible and possible.

Some of the interesting variations between each of the individual groups were observed.

Although the airway width was relatively less in class I malocclusion than in class III cases, it was observed that there was marked constriction in 20% of the sample. According to the result of the study, the tongue lies highest in class I malocclusion. However, in atleast 40% of the sample, the tongue lay relatively far from the palatal vault.

The lower sagittal airway width in class II malocclusion is much less than class III malocculsion. In 20% of cases, the airway showed marked constriction. Statistically it was proven that the tip of the tongue is retracted in class II malocculsion. However the tongue was placed well forward in 30% of the sample.

After statistical analysis, it is evident that the anterior part of the tongue in class III cases rests significantly lower than class I and class II cases. However, it was observed that in about 30% of cases, the tongue lies at relatively high level against the palate.

COMPARISONS WITH OTHER STUDIES:

Balters[1] in the late 40's and early 50's wrote many articles in which he incriminated the tongue as the prime cause of malocclusion. According to **Balters**[1] philosophy, class II malocculsion are a consequence of a backward position of the tongue. He has also reasoned that class III conditions are due to a more forward position of the tongue. He would explain class I malocclusion as being due to lack of transverse development of dentition, as a consequence of a weaker tongue when compared with the strength of buccinator mechanism.

This study validates **Balters**[1] hypothesis with regard to class III malocculsion that the tongue lies both low and forward in relation to the palate in majority of class III cases. It also confirms that the tongue is indeed retracted and held back in most of class II malocculsion.

Rakosi[13] in 1982 studied the tongue position using his template. He found that the dorsum of the tongue is relatively high in class II malocculsion. In the case of deep overbite, he found the dorsum of the tongue high at the back and low in the front.

This study shows that the posterior part of the dorsum of the tongue was relatively high in all the cases while it differ in anterior part of the tongue.

The study showed that the anterior part of the dorsum of the tongue was highest in class I followed by class II cases. The reason for this could be that most of the sample of class II cases used for the study were deep bite cases which generally, as stated by **Rakosi**[13], have a dorsum position lowered as compared to class II cases without deepbite.

This study showed that in class III malocclusion, the dorsum of the tongue had a significantly lower profile than in class I and class II. This finding is consistent with that of **Rakosi**[13] and **Balters**[1]**.**

Rakosi[13] also found that the tip of the tongue is considerably retracted in class II cases. Retraction is less in class III and class I cases. This finding is consistent with the findings of this study.

Genisor[22] has emphasized the importance of pharyngeal airway, and described how pharyngeal inflammation leading to respiratory embarrassment could lead to a forward posture of tongue and development of class III malocclusion.

This study proved that the lower oropharyngeal width is definitely increased in class III cases. This may indicate a forward tongue posture which could possibly be one of the etiological factors of class III malocclusion.

Erdem and Arat[54] measured the nasooropharyngeal area and could not find any relationship with the ANB angle. In our study, the areas of the nasopharynx and oropharynx were measured separately, as opposed to the study made by **Erdem and Arat**[54] and it was observed that the oropharyngeal airway is larger in class III cases.

Kerr[65] investigated the relationship between the nasopharyngeal and dentofacial structures on the subjects with normal and class II malocclusion, and found that the subjects with class II malocclusion has a larger nasopharyngeal airway area than normal occlusion subjects when nasal function is not normal. He also stated that there is low correlation between the nasopharyngeal and dentofacial structures when the nasal function is normal. Since our sample consist of the subjects with normal breathing pattern, our finding, in which the nasopharynx dimension are not affected by ANB angle support this view.

Linder Aronson[34] and **Woodside**[50] have also found that the sagittal depth of the bony nasopharynx is a relatively independent variable in relation to other dimensions of facial complex. Our findings validates this view.

The fact that the larger the ANB angle in class II malocclusion, the lesser the oropharyngeal area may be attributable to a different location of tongue and mandible in class II malocclusion than in other skeletal configurations, as stated by **Balters**[1]**.**

Ceylan *et al.,*[54] in their study on pharyngeal size in different skeletal patterns claimed that the nasopharyngeal area was not affected by ANB angle. This was in accordance with our findings. He also proposed that the oropharyngeal airway becomes smaller in class II malocclusion. However we have not found any significant difference between class I and class II malocclusion subjects but there was significant difference between class II and class III.

Clinically, this knowledge is useful in diagnosing developing class III malocclusion. One of the possible causes of the forward placement of the tongue could be because of respiratory embarrassment. This could be due to enlarged adenoids.

During treatment, specially space closure, it has been noticed that extraction spaces in patients with large and forwardly placed tongue are more difficult to close.

We know that the tongue is extremely adaptive to it's environment. However it is of paramount importance to correct swallowing pattern as well as the posture of the tongue to a certain extent, if long term stability is the goal. This is specially important in cases of open bite and also in patients with tongue thrusting habits, to prevent relapse of the corrected dentition.

It is suggested that this study with much bigger samples be conducted with an adequate number of subjects in each of Angle's groups so as to draw more accurate conclusions.

SUMMARY AND CONCLUSION

The role of the tongue in causing malocclusion has been a source of conflicting opinions for many years. Many orthodontists have felt that the tongue plays an important role in causing malocclusions. But, it's precise role has not been conclusively established. **Balters**[1] said that the tongue acts as a centre of reflex activity in the oral cavity. It is reasonable to expect that the tongue posture is a reflection of sagittal pharyngeal dimension, because tongue posture would have to be altered to maintain a physiologically vital airway space.

The purpose of this study was to determine the validity of **Balters**[1] hypothesis concerning tongue posture and skeletal development. An attempt was also made to correlate the sagittal airway depth to tongue posture and indirectly to malocclusion.

The tongue position and the sagittal airway dimension was measured in 50 patients. Out of total sample of 50 patients, 20 were class I, 20 were class II and 10 were class III. The following parameters were used: Tg1, Tg2, Tg3, Tg4, Tg5, Tg6, Tg7, Ut-NL, TgL, TGH, AA-PNS, APW2 - PPW2, APW4-PPW4, BA-PNS, P3, MP-LP, ptm-ppw, LPW and PAS.

The result were subjected to ANOVA and unpaired t-test.

SIGNIFICANT FINDINGS OF THE STUDY

1. The root and posterior aspect of the dorsum of the tongue, lie at the same level in the oral cavity in all the three classes of malocclusion.

2. The anterior part of the dorsum of the tongue, lies at a significantly lower level in class III than class I and class II cases. In class I and class II cases, the tongue lies nearly at the same level, however, it is marginally higher in class I cases.

3. The tip of the tongue is significantly retracted in class II cases when compared to class I cases. In class III too, the tongue is retracted in comparison with class I cases, though only marginally.

4. Tongue length is significantly shorter in class III cases when compared to class I and class II cases.

5. The upper oropharyngeal width is about the same in all the three classes of malocclusion.

6. The lower oropharyngeal width is significantly increased in class III when compared to class I and class II cases.

Through this study, it has been proved that in class III malocclusion, the tongue lies low and forward in relation to the palate in the majority of cases. It also confirms that the tongue is retracted in most cases of class II malocclusion. Thus this study validates **Balters**[1] view in case of both class II and class III malocclusion.

From the clinical point of view, this knowledge would be useful to us in diagnosis of developing class III malocclusion and making clinical procedures like space closure more efficient, where a forwardly placed tongue can hamper the procedure.

Suggestions for future studies to enlarge the scope of investigations have been made.

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